"On the Selective Conductivity exhibited by certain Polarising Substances."

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In my paper "On the Polarisation of Electric Rays by Double-refracting Crystals" (*vide* 'Journal of the Asiatic Society of Bengal,' May, 1895), and in a subsequent paper "On a New Electro-Polariscope" ('Electrician,' 27th December, 1895), I have given accounts of the polarising property of various substances. Amongst the most efficient polarisers may be mentioned nemalite and chrysotile. Nemalite is a fibrous variety of brucite. In its chemical composition it is a hydrate of magnesia, with a small quantity of protoxide of iron and carbonic acid. This substance is found to absorb very strongly electric vibrations parallel to its length, and transmit those that are perpendicular to the length. I shall distinguish the two directions as the directions of absorption and transmission. Chrysotile is a fibrous variety of serpentine. In chemical composition it is a hydrous silicate of magnesia. Like nemalite, it also exhibits selective absorption, though not to the same extent. The transmitted vibrations are perpendicular, and those absorbed parallel to the length. Different varieties of these substances exhibit the above property to a greater or less extent. I have recently obtained a specimen of chrysotile with a thickness of only 2·5 cm.; this piece completely polarises the transmitted electric ray by selective absorption.

The action of these substances on the electric ray is thus similar to that of tourmaline on light. It may be mentioned here that I found tourmaline to be an inefficient polariser of the electric ray; it does transmit the ordinary and the extraordinary rays with unequal intensities, but even a considerable thickness of it does not completely absorb one of the two rays.

In Hertz's polarising gratings, electric vibrations are transmitted perpendicular to the wires, the vibrations parallel to the wires being reflected or absorbed. Such gratings would be found to exhibit electric anisotropy, the conductivity in the direction of the wires being very much greater than the conductivity across the wires. The vibrations transmitted through the gratings are thus perpendicular to the direction of maximum conductivity—or parallel to the direction of greatest resistance. The vibration absorbed is parallel to the direction of maximum conductivity.

As the nemalite and chrysotile polarised the electric ray by unequal absorption in the two directions, I was led to investigate whether

they, too, exhibited unequal conductivities in the two directions of absorption and transmission.

Nemalite, unfortunately, is difficult to obtain, and the specimens I could get here were too small to make the necessary measurements. I have, however, in my possession two specimens which I brought from India; of these, one is a perfect specimen of a fair size, and I obtained with it strong polarisation effects. The second piece is not as good as the first, and rather small in size. I cut from this latter piece a square of uniform thickness, the adjacent sides of the square being parallel to the directions of transmission and absorption respectively. The resistances of equal lengths in the two directions (with the same cross section) were now measured.

The first specimen I gave to Messrs. Elliott Brothers for measurement. They informed me, on the 13th of October last, that the resistance in the direction of transmission was found to be 35,000 megohms, and that in the direction of absorption, only 14,000 megohms.

It will thus be seen that the direction of absorption is also the direction of greatest conductivity, and the direction of transmission is the direction of least conductivity.

My anticipations being thus verified, I proceeded to make further measurements with other specimens. From the perfect specimen of nemalite in my possession, I cut two square pieces, A and B. The size of piece A is $2{\cdot}56 \times 2{\cdot}56$ cm., with a thickness of $1{\cdot}1$ cm. B is $2{\cdot}76 \times 2{\cdot}76 \times 1{\cdot}2$ cm.

For the determination of resistances I used a sensitive Kelvin galvanometer, having a resistance of 7000 ohms. With three Leclanché cells, 1·4 volt each, and an interposed resistance equivalent to 55,524 megohms, a deflection of 1 division in the scale reading was obtained. The following table (p. 435) gives the results of the measurements which I carried out.

The results given clearly show how the difference of absorption in the two directions is related to the corresponding difference in conductivity.

I then proceeded to make measurements with chrysotile. The specimens I could obtain were not very good. I cut two from the same piece, and a third specimen was obtained from a different variety. The ratios of conductivities found in the three specimens were 1 : 10, 1 : 9, and 1 : 4 respectively. In every case the direction of absorption was found to be the direction of maximum conductivity.

[A fibrous variety of gypsum ($CaSO_4$), popularly known as Satin-spar, also exhibits double absorption; and in this case, too, the conductivity in the direction of absorption is found to be very much greater than in that of transmission.

Specimen A.	Deflections.	Resistance between two opposed faces 2·56 × 1·1 cm. separated by 2·56 cm.	Ratio of the conductivities.
In the direction of transmission	26	2136 megohms	1 : 13·8
,, ,, absorption..	360	154 ,,	

Specimen B.	Deflections.	Resistance between two opposed faces 2·76 × 1·2 cm. separated by 2·76 cm.	Ratio of the conductivities.
In the direction of transmission	28	1983 megohms	1 : 13·4
,, ,, absorption..	370	150 ,,	

One of the strongest polarising substances I have come across is the crystal epidote. The crystal is very small in size, and I could not get with it complete absorption of one of the two rays. But it exhibits very strong depolarisation effect, even with a thickness as small as 0·7 cm. This is, undoubtedly, due to strong selective absorption in one direction. I cut a square from this crystal 0·7 × 0·7 cm. with a thickness of 0·4 cm. Using an E.M.F. of 14 volts the deflections obtained (proportional to the two conductivities) were 105 and 20 divisions respectively. The conductivities in the two directions are, therefore, in the ratio of 5·2 : 1. With an E.M.F. of 100 volts and a diminished sensibility of the galvanometer, the deflections were 205 and 40, the ratio of the conductivities being as 5·1 : 1.—*January* 28, 1897.]

It would thus appear that substances like nemalite which polarise by double absorption, also exhibit double conductivity. It is probable that, owing to this difference of conductivity in the two directions, each thin layer unequally absorbs the incident electric vibrations; and that by the cumulative effect of many such layers, the vibrations which are perpendicular to the direction of maximum conductivity are alone transmitted, the emergent beam being thus completely polarised.

[Owing to the great difficulty in obtaining suitable specimens, I have not been able to make a more extended series of determinations. The relation found, in the cases described above, between double absorption and double conductivity is, however, suggestive.

It should, however, be borne in mind that the selective absorption exhibited by a substance depends, also, on the vibration frequency of the incident radiation. I have drawn attention to the peculiarity of tourmaline which does not exhibit double absorption of the electric ray to a very great extent. The specimen I experimented with is, however, one of a black variety of tourmaline, and not of the semi-transparent kind generally used for optical work.

Though the experiments already described are not sufficiently numerous for drawing a general conclusion as to the connection between double absorption attended with polarisation, and double conductivity, there is, however, a large number of experiments I have carried out which seem to show that a double-conducting structure does, as a rule, exhibit double absorption and consequent polarisation. Out of these experiments I shall here mention one which may prove interesting. Observing that an ordinary book is unequally conducting in the two directions—parallel to and across the pages—I interposed it, with its edge at 45°, between the crossed polariser and analyzer of an electro-polariscope. The extinguished field of radiation was immediately restored. I then arranged both the polariser and the analyzer vertical and parallel, and interposed the book with its edge parallel to the direction of electric vibration. The radiation was found completely absorbed by the book, and there was not the slightest action on the receiver. On holding the book with its edge at right angles to the electric vibration, the electric ray was found copiously transmitted. An ordinary book would thus serve as a perfect polariser of the electric ray. The vibrations parallel to the pages are completely absorbed, and those at right angles transmitted in a perfectly polarised condition.—*January* 28, 1897.]